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THE DESIGN OF BLAST CONTAINMENT ROOMS FOR DEMILITARIZATION OF CHEMICAL MUNITIONS

BY

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INTRODUCTION

This paper presents a short discussion of the design of blast hardened containment rooms within a new facility being developed to perform demilitarization of obsolete chemical munitions. This facility will perform the demilitarization operations required on a production basis and will conform to all required safety and environmental regulations. The hazard potential associated with chemical munitions dictates that process operations related to removing explosive components must provide complete containment of blast pressures and fragmentation and near total containment of quasi-static gas pressure. Widely used hardened structures design procedures were the foundation of this effort. However, the unique nature of chemical munitions dictated development of additional test data and prediction methods to properly define the blast and fragment loadings.

Additional design considerations, which develop as a result of full containment, are also discussed. The concept of "full containment" itself has a different context when discussing blast and fragments as opposed to confinement of toxic gas products.

The facility being discussed is the Johnston Atoll Chemical Agent Disposal System (JACADS). This facility is under design and will be sited on Johnston Atoll where an existing stockpile of chemical munitions earmarked for disposal is located. This is the first of several new disposal plants planned for construction over the next several years. Management responsibility for the chemical demilitarization program rests with the U.S. Army Toxic and

Hazardous Materials Agency (USATHAMA) located at Aberdeen Proving Ground, MD. The Huntsville Division (HND) of the U.S. Army Corps of Engineers is acting as the contracting authority for the design of the JACADS process and main process facility. The process design is being performed by the Ralph M. Parsons Company under contract to HND. The facilty design is being performed concurrently with the process by Stearns-Catalytic. Technical review of these design efforts is being performed by USATHAMA and HND engineering staff. Specialized consultants are also used where necessary. Among these, Southwest Research Institute has provided major support in the area of blast and fragment analysis.

FUNCTIONAL DESCRIPTION

The JACADS Facility houses a production process which will accept several types of chemical munitions and perform the necessary operations to safely separate explosive components and liquid agent from the munitions and then incinerate the explosives and agent and thermally decontaminate the metal parts. All process operations are conducted in a single building. Figure 1 shows the JACADS facility site, including the layout of the various equipment and other facilities required to support the main process building, the Munitions Demilitarization Building (MDB). Within the MDB the ventilation system is designed to provide increasing levels of negative pressure from non-hazardous areas towards hazardous areas. This prevents leakage of toxic vapors from hazardous areas to other areas. Those munitions with explosive components are placed in two functionally identical explosive containment rooms (ECRs) on the

second floor of the building. The explosive components are removed by automatic equipment and then gravity fed to an incinerator on the first floor. Figure 2 shows the MDB second floor ECRs, and Figure 3 shows the first floor with the Deactivation Furnace System (DFS) below.

The hazardous nature of the explosive removal operations required Category 1 blast and fragment protection for the remainder of the building. This required the two ECRs to provide total containment. It was also necessary that the two rooms provide a high degree of vapor containment after an explosive incident. The high production rates required of the facility generated several operational requirements which influenced containment room design. These are listed in Figure 4. The influence of each of these requirements on the design of the blast containment rooms is discussed.

TOTAL CONTAINMENT OF BLAST AND FRAGMENT EFFECTS

The required operational configuration of the ECRs and the remote construction site dictated reinforced concrete as the most cost effective construction material. Well proven methods are available for designing blast resistant, reinforced concrete structures (Ref. 1), given the expected blast and fragment environment. Because chemical munitions are designed to function differently than the more typically encountered fragmenting rounds, it became necessary to develop additional blast and fragment data to predict loads. Figure 5 summarizes this effort. The results of these sources (Ref. 2 and 3) were the basis of the blast pressures and fragments used in the design. It is significant to note that fragmentation of the chemical munitions considered

resulted in more severe fragment shapes and depths of penetration than would have been calculated using Reference 1.

CONTAINMENT OF GAS PRESSURE

The highly toxic nature of the chemical agents in the munitions dictated that the ECRs provide a high degree of containment of the post-accident gas products. This near total containment of high temperature contaminated gas must be maintained until the heat is conducted away by the structure. As the gas cools, the temperature and pressure will drop and eventually reach a level where it can be safely processed through the building ventilation system. Figure 6 shows a temperature/pressure decay curve for the ECRs after a typical accident scenario. No concrete structure can be expected to be completely gas tight unless a liner plate is provided. The cost of a liner plate is significant, and the risk of agent contamination behind the liner was undesirable. An alternate course of action was to use an unlined concrete structure that was contained within an outer negative pressure ventilation area which was capable of handling any small leakage through the ECR structure. This concept is shown in Figure 7 and was chosen as the basis of design. Results of explosive model testing (Ref. 4) for a similar concrete containment structure was used to predict outgassing through the concrete after an incident. Leakage through the structure is a direct function of the internal pressure after an event. As the confined gas cools, pressure decays fairly rapidly; and the leakage rate decreases proportionately. Figure 8 shows graphically the comparison of pressure drop due to leakage relative to pressure drop from cooling. Analysis has shown that total leakage is only a small percentage of the allowable leak rate in the surrounding areas.

VENTILATION SYSTEM BLAST PROTECTION

Process operations in the ECR can result in the introduction of agent vapor into the room. To minimize this hazard a high ventilation rate is maintained continuously during process operations. In the event of an explosive incident, the supply and exhaust ducts must be quickly isolated from the ECR to prevent serious damage and personnel risk to the remainder of the building. To accomplish this each duct has a fast-acting blast valve in series with a gas-tight valve which is tied into the process control system. Figure 9 shows the blast protection for the ECRs. The blast valves protect the ventilation system from shock pressures and the controllable gas-tight valves provide positive isolation capability for other situations. It is interesting to note that, even though fast-acting blast valves are used, an attenuated shock will pass the valve and enter the ventilation system. The peak value of the shock is a function of losses through the valve and the duration depends on the valve closure time. For the ECR design, peak shocks at the valve inlet were derived from scale model test data. Shock intensity after the valves are obtained from the valve manufacturer's test data. Figure 10 shows the typical ECR shock pulse upstream and downstream of the valves. This "leakage" shock was then traced through the ventilation system to assure no risks to the system or personnel occurred.

BLAST RESISTANT PENETRATIONS

All doors, conveyor gates and drop chutes in the ECRs must provide blast and fragment resistance, be operationally reliable and be as air tight as

feasible. The worst case fragments in the ECR design required a steel thickness of 2.5 inches. Obviously, plates of this thickness resulted in complex hinge assemblies and powered operating mechanisms. All operating closures are tied to the process control system and interlocked to assure closing during hazardous operations. Door assemblies are installed in the ECR prior to placing concrete to assure a reliable installation. All conveyor gates and doors will have compression seals to limit leakage after a blast to specified maximum valves.

SURFACE COATING MATERIALS

Day-to-day exposure of the ECR to agent vapor required that all interior surfaces be coated with an agent resistant epoxy paint. This finish prevents agent from impermeating the concrete and provides a smooth resistant finish for regular washdown with decontamination solutions. The coating also significantly improves the gas tightness of the structure.

The use of this coating raised the question of potential combustibility causing an increase in the quasi-static gas pressure. Figure 11 presents the classical pressure-time history within a containment structure. It consists of a high peak, short duration shock pressure, followed by a relatively long-term quasi-static pressure which decays as the gas cools. Figure 12 shows a reproduction of a pressure trace of a model containment structure (Ref. 4) in which a wall coating material used to seal the structure apparently burned. The increase in gas pressure is dramatic.

Available data on the proposed wall coatings was not sufficient to assure its combustion characteristics when exposed to a fireball, as would occur during an accidental incident. A test program (Ref. 5) was therefore conducted to evaluate the three coatings which were acceptable from the standpoint of agent resistance. Results proved that these particular materials did not pose a risk with regard to combustion pressures. It is interesting to note that this issue is normally not even considered in a vented structure.

STRUCTURE REUSABILITY

In the event that an explosive incident occurred during normal operations, it is desirable to limit damage to minor refurbishment efforts so that the ECR can be brought into service quickly. To achieve this, structural damage criteria was defined as shown in Figure 13. These criteria are much more restrictive than values normally used in hardened structure design. This assures a higher degree of containment. Inelastic deformation is very useful and desirable when a transient load is to be resisted. In the case of a containment structure, this condition exists during the shock phase of the loading and up to the time of maximum response of the structural element. However once this transient load has passed, the remaining quasi-static load is basically steady-state. During this phase, the maximum design deformation must be within the elastic limit of the element. Similar logic applies to the use of Dynamic Increase Factors (DIF) which increase material allowables based on rate of strain during loading. Use of a DIF during the quasi-static phase is not appropriate.

SUMMARY

Design of concrete structures for full containment applications is generally similar to design of other hardened structures, such as vented cubicles. Several additional factors can be present which must be considered to assure a complete evaluation of the loading and the structure response. Several recent model tests (Ref. 4, 5 & 6) have supported the design philosophies applied to these containment rooms.

1. "Structures to Resist the Effects of Accidental Explosions," U.S. Army Technical Manual TM 5-1300, Washington, DC, June 1969.

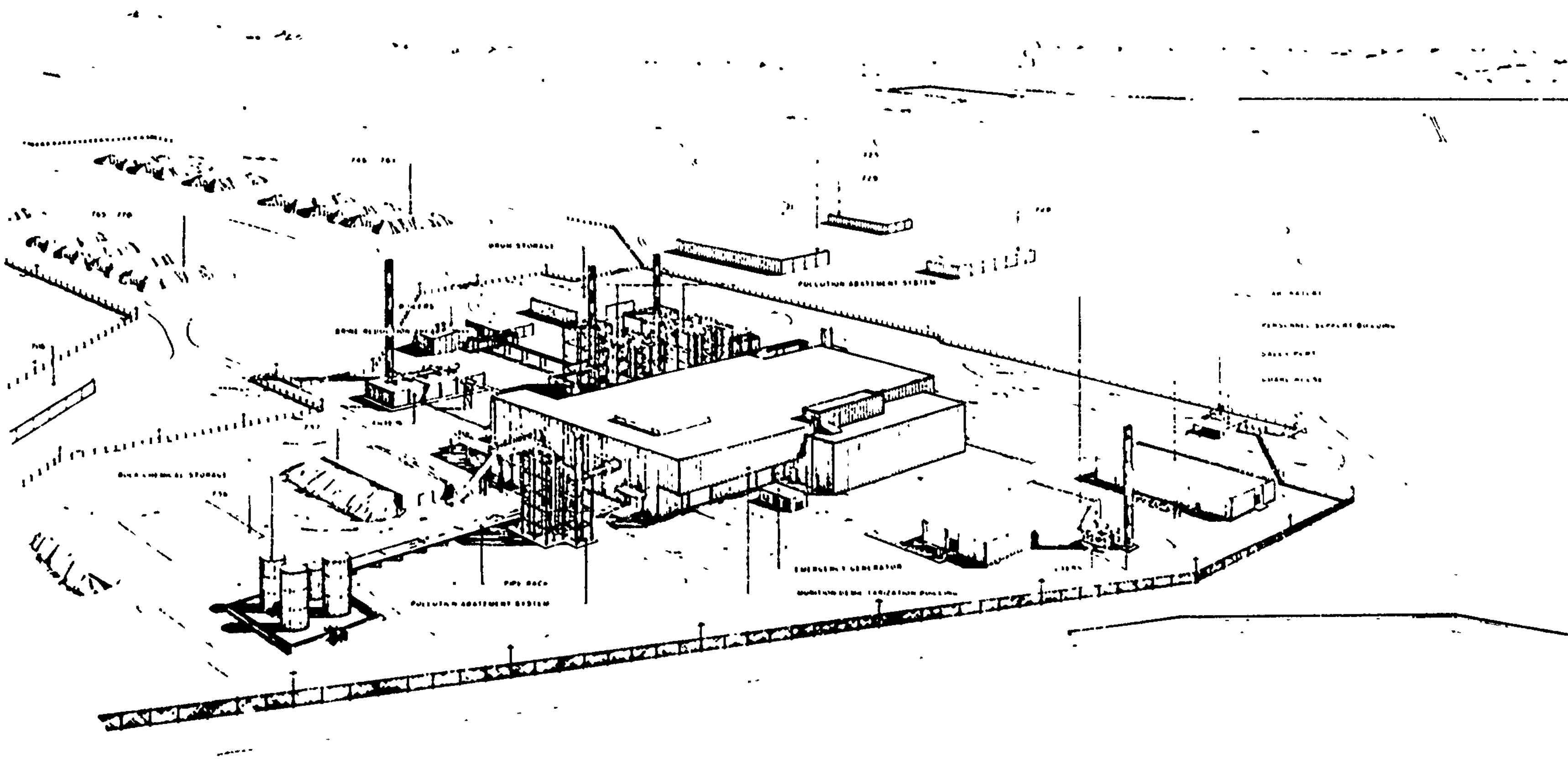
2. Whitney, M. G., Friesenhahn, G. J., Baker, W. E., and Vargas, L. M., "A Manual to Predict Blast and Fragment Loadings from Accidental Explosions of Chemical Munitions Inside an Explosive Containment Structure," U.S. Army Toxic and Hazardous Materials Agency, April 1983.

3. Powell, J. G., "Fragment Characterization Profile for Chemical-Filled Munitions - M23 Land Mine, 115MM Rocket Warheads and 8-inch Projectile," Naval Surface Weapons Center, April 1983.

4. "Kirtland Underground Munitions Storage Complex Model Designs Construction and Test Data," Technical Report (Preliminary, Unnumbered), prepared for Defense Nuclear Agency by U.S. Army Waterways Experiment Station, April 1984.

5. "JACADS Explosive Containment Room Model Test," Southwest Research Institute Project 06-8069, prepared for the U.S. Army Engineer Division, Huntsville, July 1984.

6. Hokanson, J. C., Esparza, E. D., Baker, W. E., Sandoval, N. R., and Anderson, C. E., "Determination of Blast Loads in the Damaged Weapons Facility, Volume 1, Final Report for Phase II," SWRI Project 06-6578, Mason & Hanger-Silas Mason Company, Inc., Pantex Plant, Amarillo, Texas, July 1982.



PERSPECTIVE VIEW OF SITE
JOHNSTON ATOLL CHEMICAL AGENT DISPOSAL SYSTEM JACADS

Figure 1

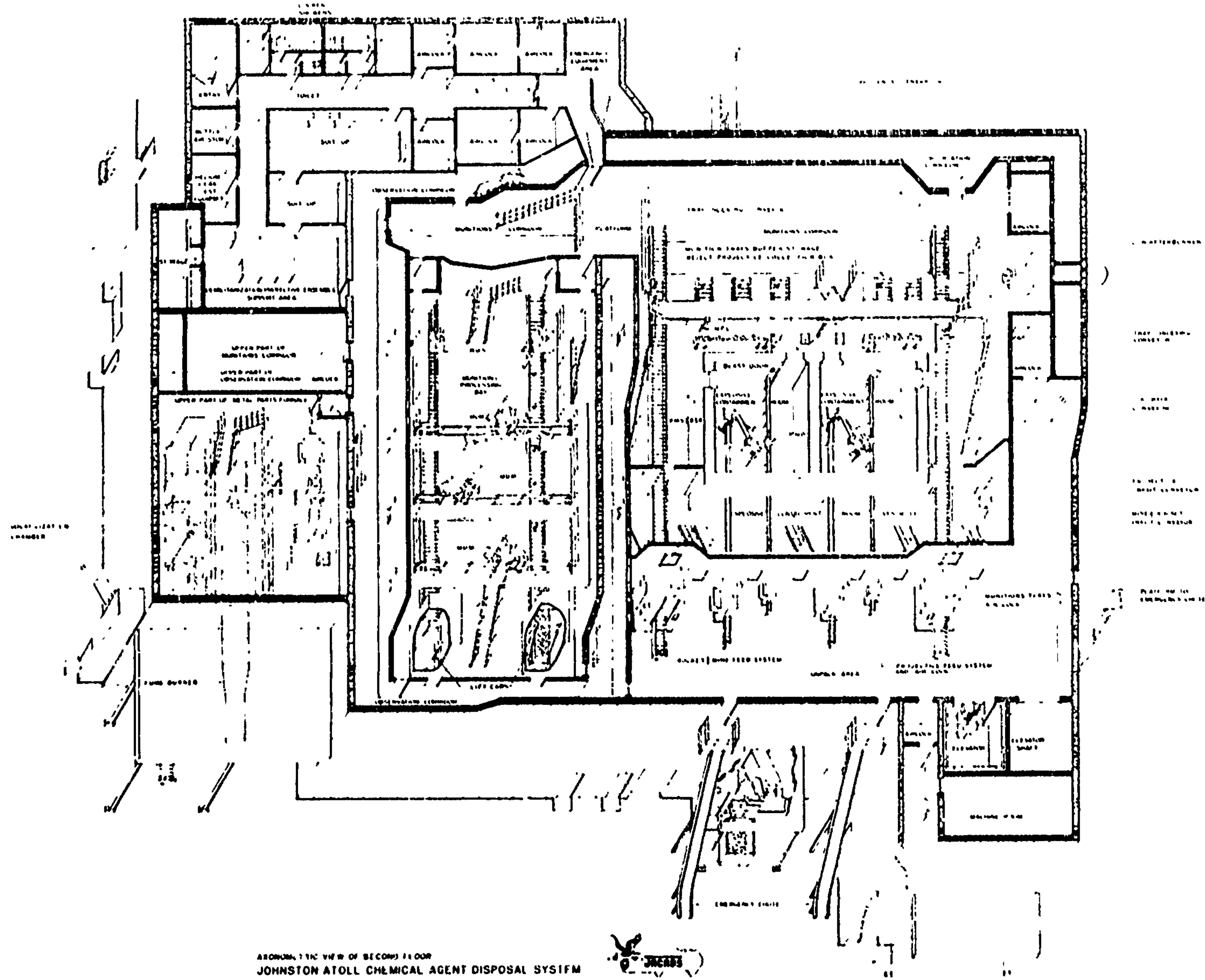
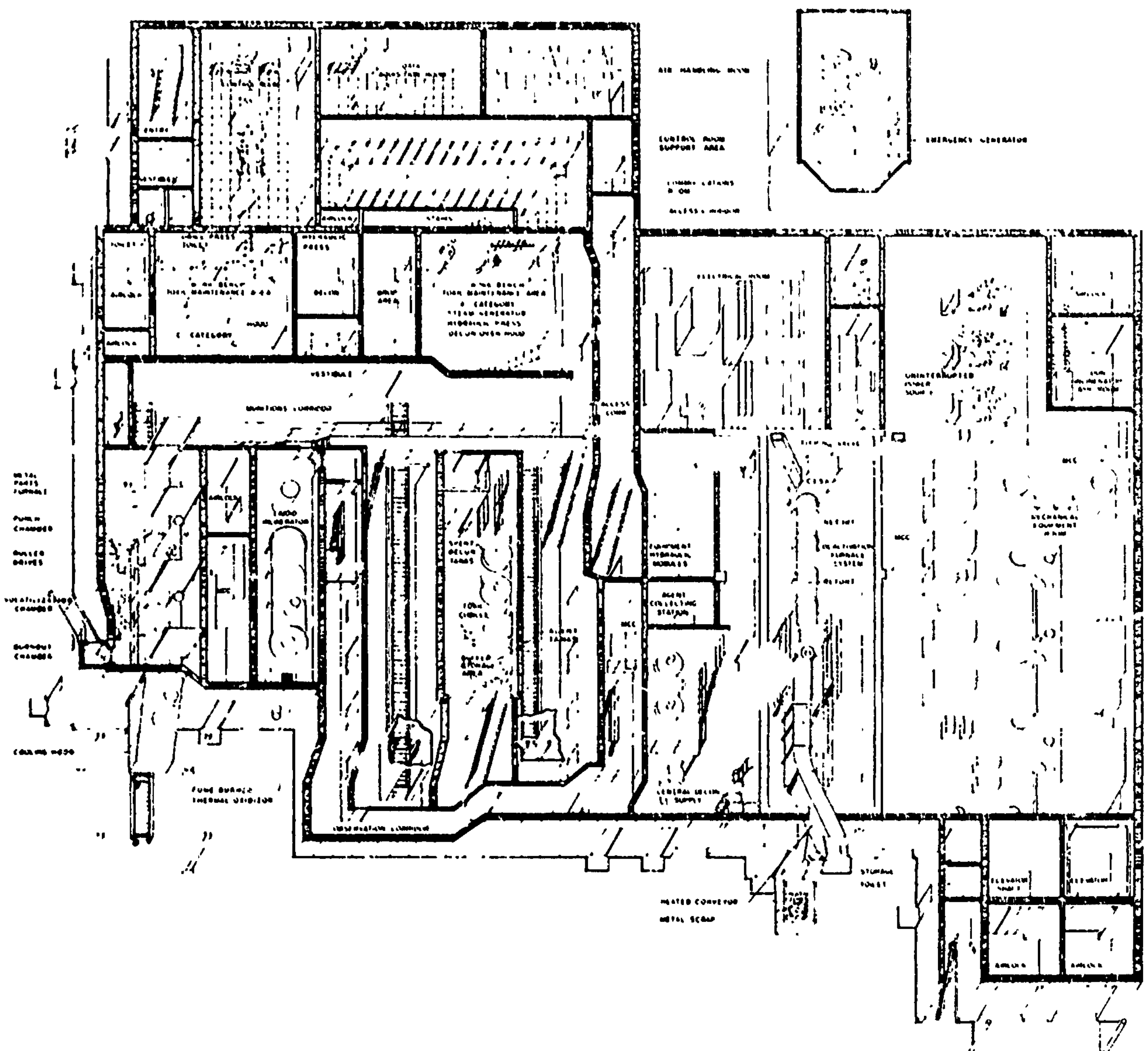

AXONOMETRIC VIEW OF SECOND FLOOR
JOHNSTON ATOLL CHEMICAL AGENT DISPOSAL SYSTEM
JACOBS

Figure 2



AXONOMETRIC VIEW OF FIRST FLOOR
JOHNSTON ATOLL CHEMICAL AGENT DISPOSAL SYSTEM

Figure 3

JACADS FUNCTIONAL REQUIREMENTS FOR EXPLOSIVE CONTAINMENT ROOMS

- TOTAL CONTAINMENT OF BLAST AND FRAGMENTATION — CATEGORY 1
- NEAR TOTAL CONTAINMENT OF POST-INCIDENT HOT GAS PRODUCTS UNTIL SAFE FOR PROCESSING
- PROVIDE CONTINUOUS VENTILATION SYSTEM PROTECTED BY BLAST VALVES
- PROVIDE BLAST RESISTANT LEAK-TIGHT DOORS, CONVEYOR GATES AND OTHER PENETRATIONS.
- INTERIOR SURFACE FINISH NON-COMBUSTIBLE, AGENT AND CAUSTIC RESISTANT
- REUSABLE AFTER EXPLOSIVE INCIDENT

FIGURE 4

BLAST AND FRAGMENTATION PREDICTION FOR CHEMICAL MUNITIONS

REQUIRED ACTION

- DETERMINE INFLUENCE OF LIQUID SURROUNDING BURSTERS ON THE BLAST AND FRAGMENT CHARACTERISTICS OF CHEMICAL MUNITIONS

RESULTS

- EXTENSIVE TEST PROGRAM AT THE NAVAL SURFACE WEAPONS CENTER TO CHARACTERIZE CHEMICAL MUNITIONS
- DEVELOPMENT OF SOUTHWEST RESEARCH INSTITUTE OF A MANUAL WHICH PROVIDES BLAST AND FRAGMENT PREDICTION METHODS APPROPRIATE FOR CHEMICAL MUNITIONS.

FIGURE 5

PRESSURE-TEMPERATURE DECAY

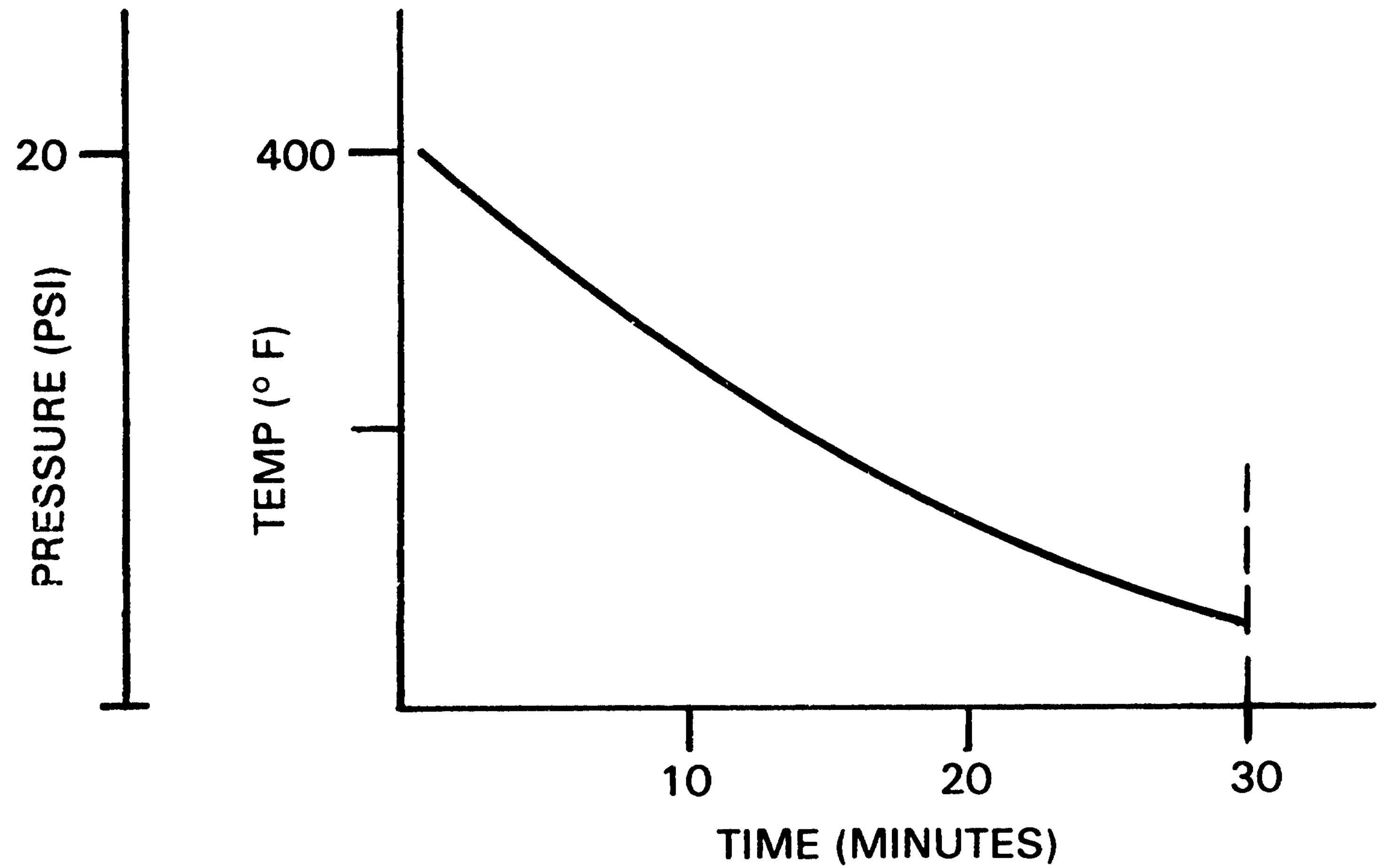


FIGURE 6

SECTION THROUGH ECR/DFS

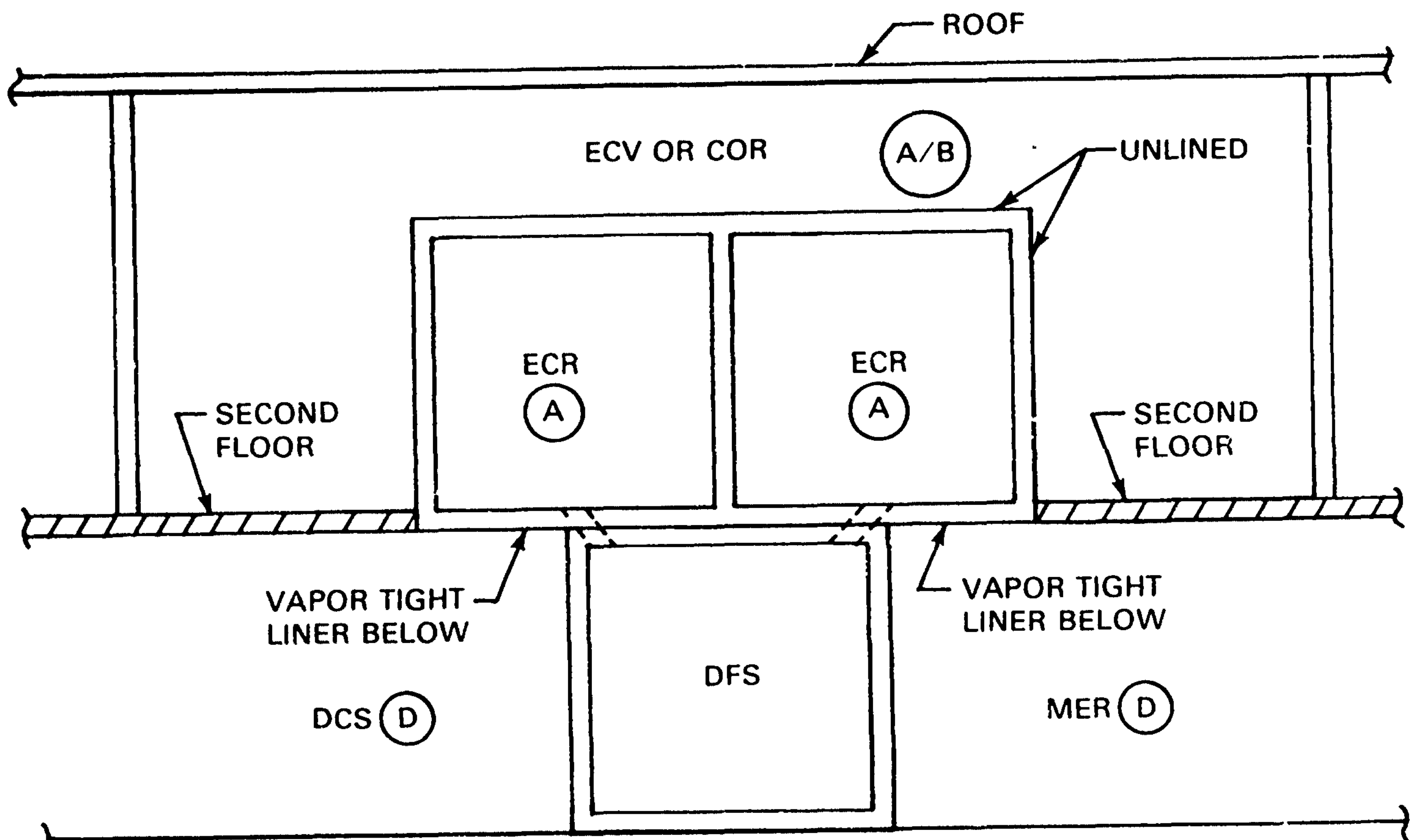


FIGURE 7

ESTIMATED LEAKAGE

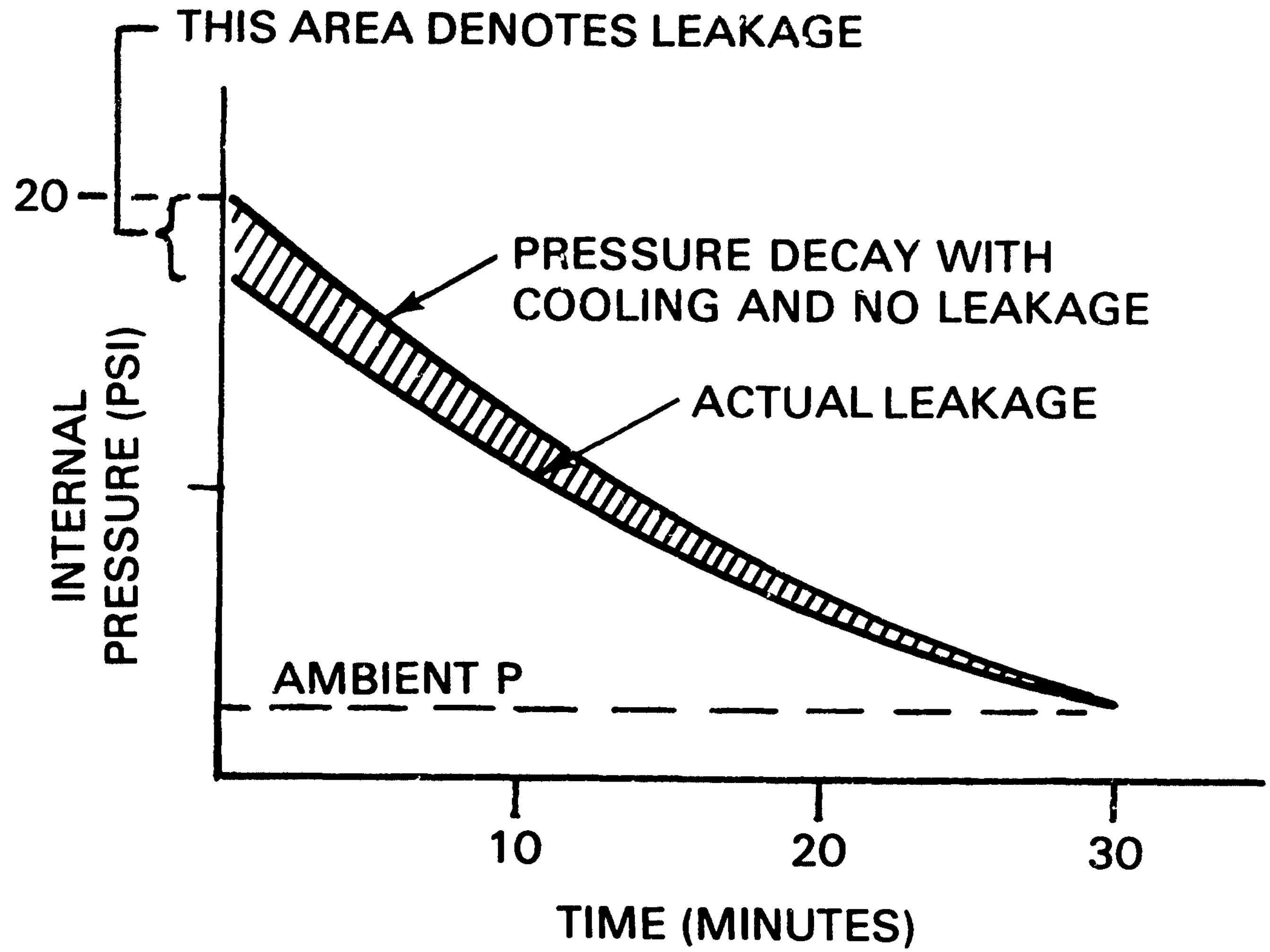


FIGURE 8

ECR VENTILATION SYSTEM BLAST PROTECTION

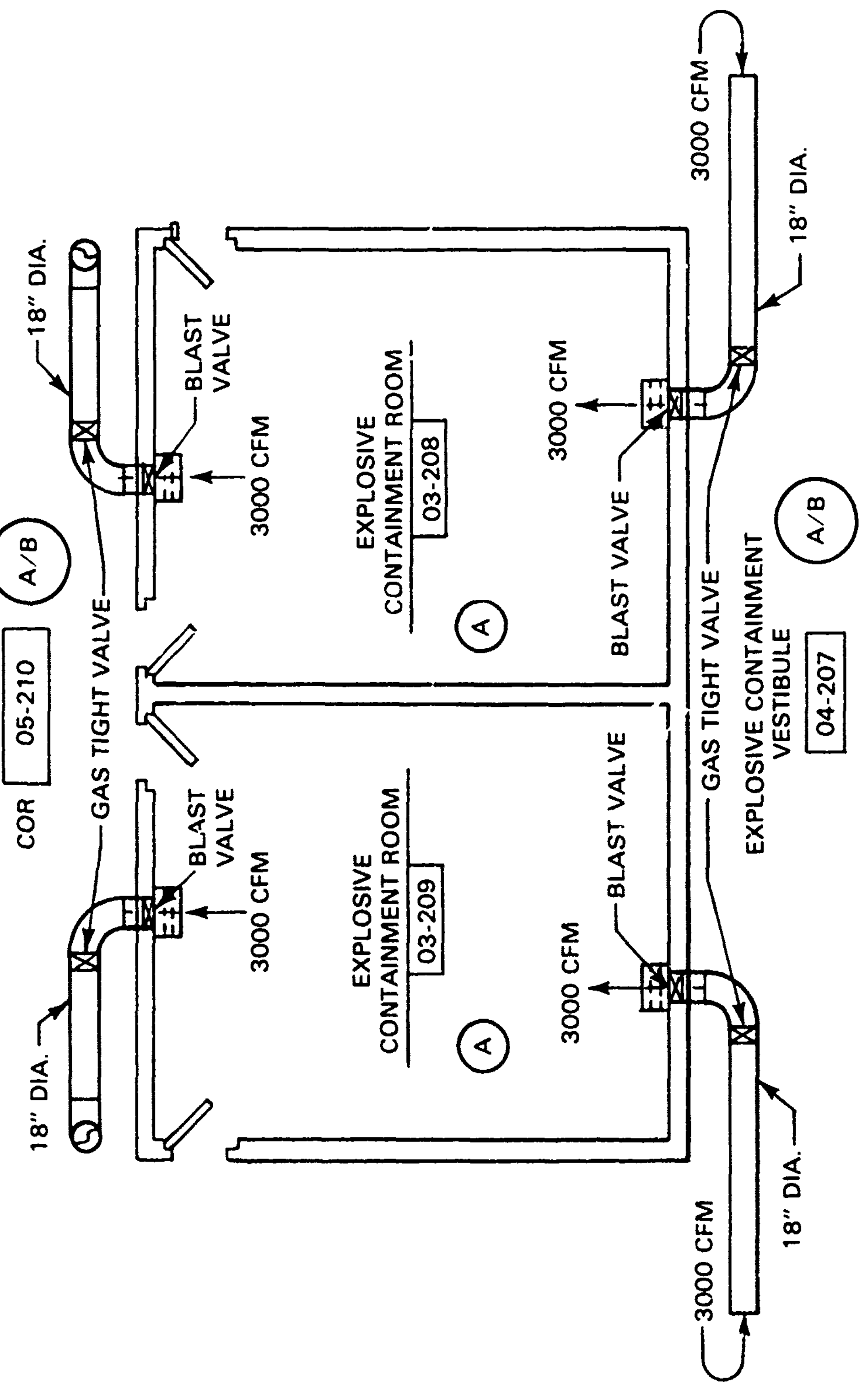


FIGURE 9

SHOCK PULSE PASSING THROUGH BLAST VALVE

SHOCK PULSE AT INLET SIDE OF BLAST VALVE

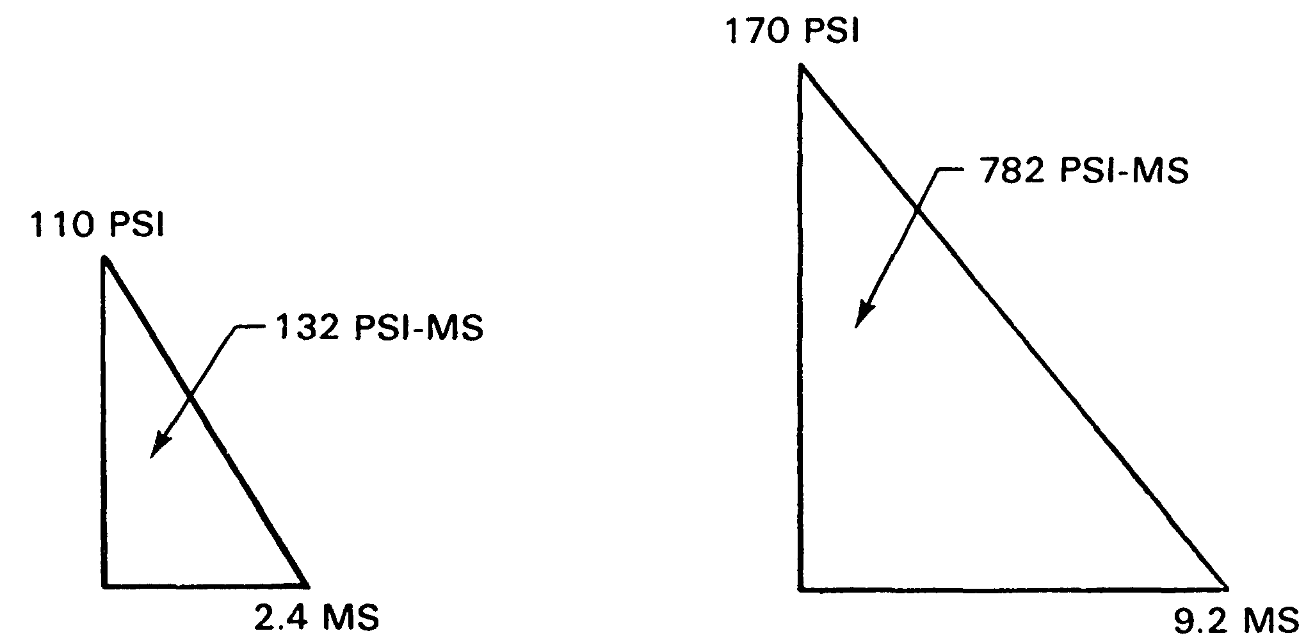


FIGURE 10

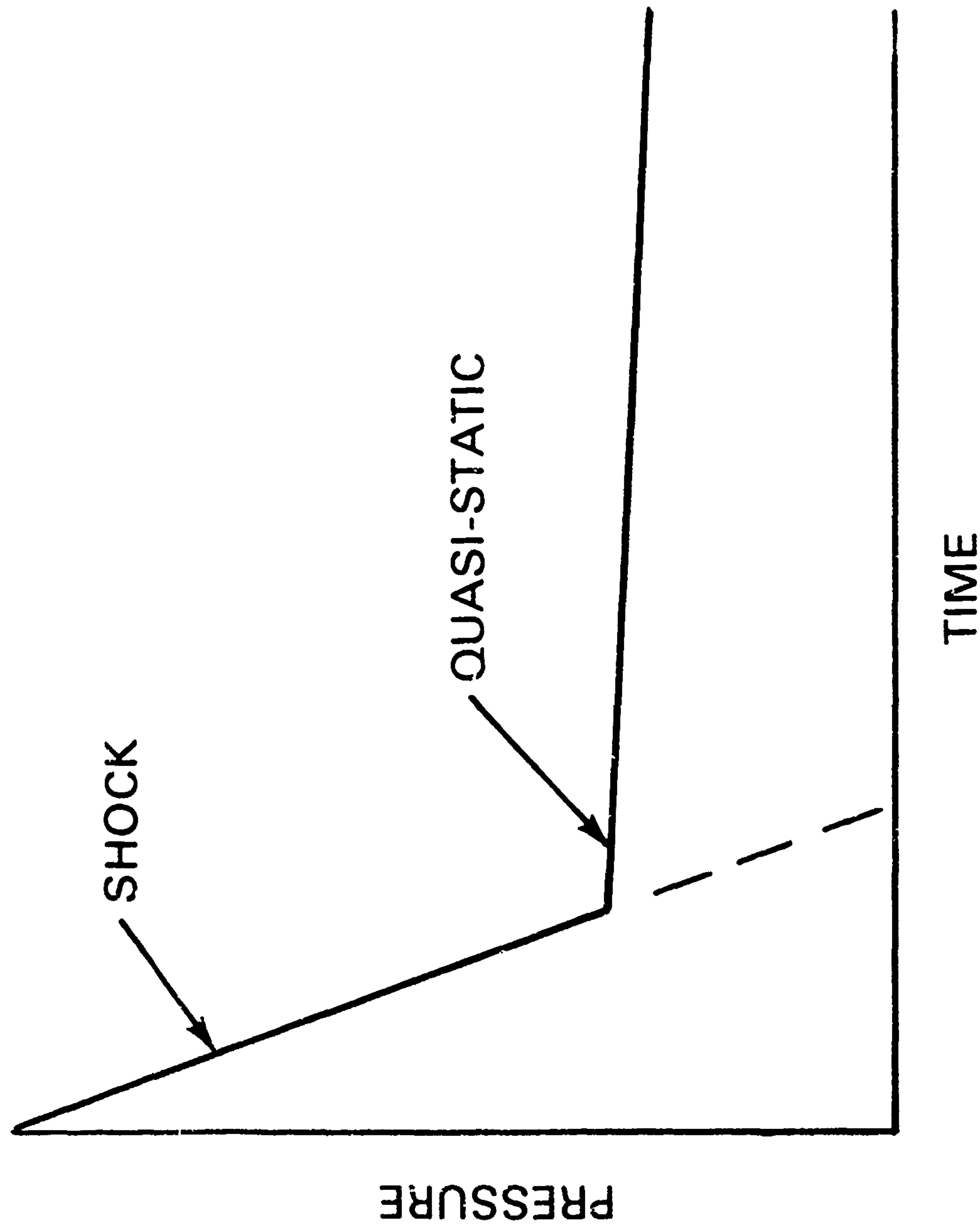


FIGURE 11

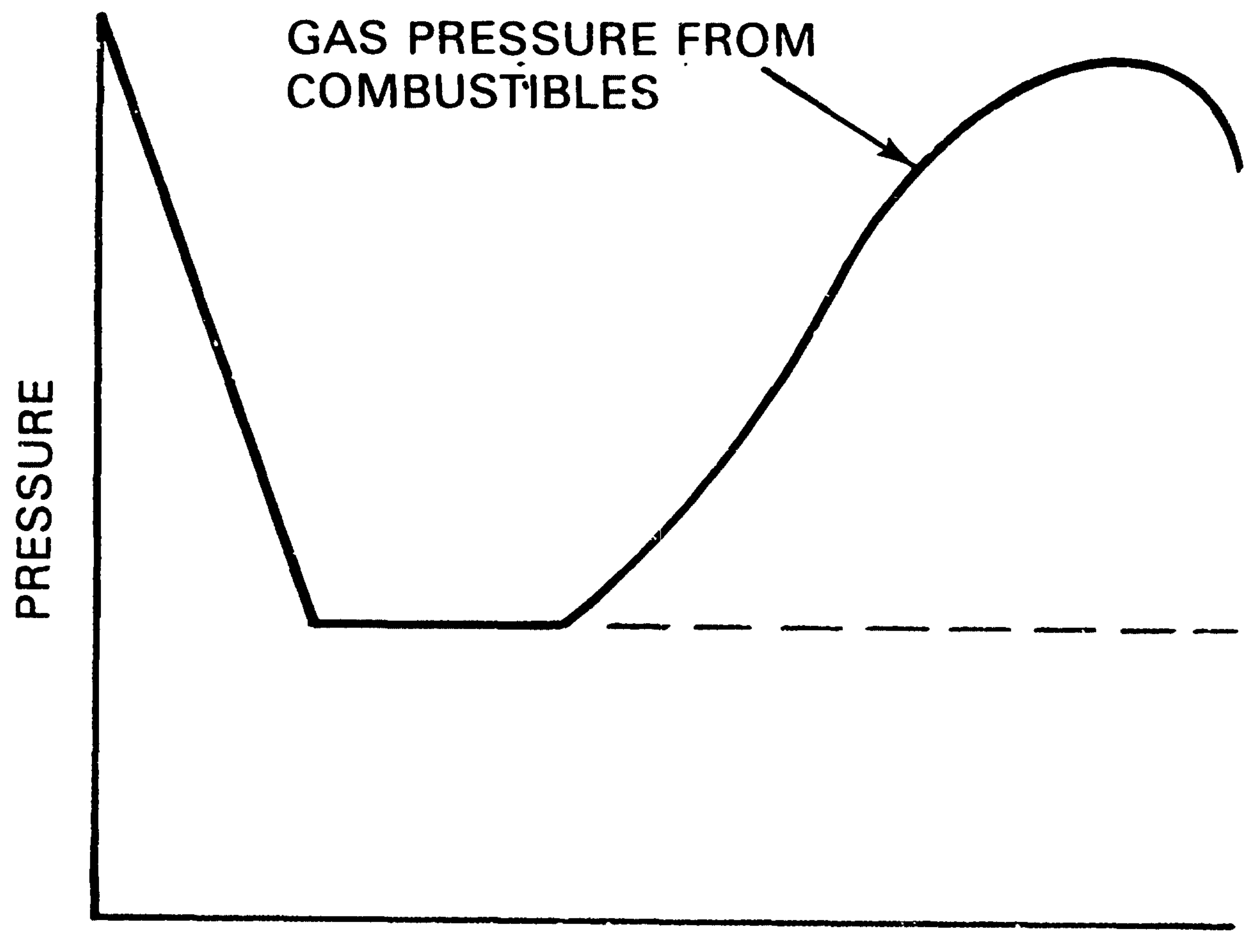


FIGURE 12

STRUCTURAL DAMAGE CRITERIA

- DURING SHOCK LOAD PHASE $T \leq T_m$ ELEMENT JOINT NOTATIONS $\leq 1°$ OR $\mu \leq 3$ DYNAMIC INCREASE FACTORS USABLE

- DURING QUASI-STATIC PRESSURE $T > T_m$ ELEMENTS MUST REMAIN WITHIN THE ELASTIC LIMIT DYNAMIC INCREASE FACTORS NOT VALID.

FIGURE 13